

such as polycarbonate is particularly useful because of its transparency and physical properties. At least one port **40a**, **42a**, **44a** extends through the outer wall of cylindrical segment **40**, **42**, **44**, respectively, for allowing the introduction and removal of materials into the respective compartments **40b**, **42b**, **44b** of the segments **40**, **42**, **44**. Although not shown, each port **40a**, **42a**, **44a** is provided with a respective removable cap for creating a fluid-tight seal.

[0036] The cylindrical segments **40**, **42**, **44** have identical outer diameters, and identical inner diameters defining their respective compartments **40b**, **42b**, **44b**. The radial and length dimensions of the segments **40**, **42**, **44** and other equipment components discussed herein may be selected based on several factors, including the desired scale of the operation. For the purposes of experiments carried out by the inventors, a tumbler was used having a length maximum of 5.56 inches (14.12 cm) overall and a maximum diameter of 2.81 inches (7.14 cm) outer diameter (OD). Clearly larger dimensions may be desirable for large or industrial scale operations.

[0037] A first filter cassette **50** is interposed between the first cylindrical segment **40** and second cylindrical segment **42** of the tumbler **32**. A plan view of filter cassette **50** is shown in FIG. 4A. As shown in FIG. 4A, the filter cassette **50** includes an annular body element **54** receivable between flanges of cylindrical segments **40** and **42**. A groove machined into the inner rim of body element **54** receives an O-ring **55** for establishing a fluid-tight seal at an interface of the segment walls. The central region of the first filter cassette **50** includes a mesh **56**. Mesh **50** may be mounted to the body element **54** as discussed below in connection with FIG. 7B.

[0038] Filter body **54** has holes or apertures **54a** for receiving a bolt, screw, or other fastener to mount the filter cassette **50** between the flanges of segments **40**, **42**. A second filter cassette **52** is similarly interposed between the second and third cylindrical segments **42**, **44**. Fewer or additional filter cassettes may be included in the tumbler **32**. Alternative mating arrangements may be used of mounting the filter cassettes **50**, **52** to the segments **40**, **42**, **44**. For example, segment **40** and/or **42** may include a shoulder for receiving the outer rim of the first filter **50**. The mesh **56** may be made of any suitable material, such as nylon mesh.

[0039] The pore dimensions of the mesh **56** of the first filter cassette **50** are sized to permit fluid, CNTs, catalytic particles, and amorphous carbon (from the CNT coating) separated from CNT bundles deposited in compartment **40b** to flow through the mesh **56** of the first filter cassette **50** into compartment **42b**, while preventing flow of a substantial portion of the larger grit particles, that is, substantially retaining the grit particles in the chamber **40b** of the first cylindrical segment **40**. The pore dimensions of the mesh of the second filter **52** may be smaller than the pore dimensions of the mesh **56** of the first filter **50** to collect in the second compartment **42b** grit particles and bundle formations small enough to have passed with the fluid flow through the first filter cassette **50**. The mesh pore dimensions of the filters **50**, **52** may be in a range of, for example, 50 nm to 100 microns. According to one exemplary embodiment, the meshes **56** of the first and second filters **50**, **52** have pore dimensions of 50 microns and 5 microns, respectively. According to another exemplary embodiment, another mesh (not shown) of about 1 micron is added downstream relative to the second filter **52**. Nylon meshes are available, for example, through Small Parts, Inc. of Miramar, Fla. An exemplary commercial 50 micron mesh sold by Small Parts, Inc. under part number CMN-0053-A is

described as 40 micron thread diameter with a 31 percent open area. An exemplary 1 micron commercial mesh is sold by Small Parts, Inc. under parts number CMN-LP001001-06. [0040] A magnetic element **59** is situated at one end of the tumbler **32**, adjacent the upstream end of the first cylindrical segment **40**. As will be explained in further detail below, the magnetic element **59** should have an attractive force sufficient to attract a substantial portion of the metallic catalysts separated from the CNT bundles during the grit shearing step **10**. The magnetic element **59** may comprise one or more neo-magnets, although other static and electromagnetic elements may be used instead of or in addition to the neo-magnet(s). An exemplary commercial 2½"×¼" neo-magnet (NdFeB, Grade N42) is sold by K&J Magnetics, Inc. of Jamison, Pa. An end closure **33** is situated at the opposite end of the tumbler **32**. The magnetic element **59** and the end closure **33** have central bores creating part of the fluid pathway for the flow of fluid pumped by the pump assembly **36**.

[0041] In an exemplary implementation, CNT bundles are introduced into the compartment **40b** of the first cylindrical segment **40** through port **40a**. The input material may be derived from any production source of CNTs, for example, chemical vapor deposition, pulsed laser vaporization, radio frequency plasma, or electric arc discharge, and can be applied to sources of CNTs with any level of initial purity, aggregate/bundle state and size distribution. The CNTs introduced into the portion **40a** may be single-wall or multi-wall structures. Commercial suppliers of CNTs include, for example, Unidym, Inc. (formerly Carbon Nanotechnologies, Inc. (CNI)) of Menlo Park, Calif., Carbolex, Inc. of Broomall, Pa., Nanolab, Inc. of Newton, Mass., and SouthWest Nanotechnologies Inc. of Norman, Okla.,

[0042] Also introduced through port **40a** are grit particles and an aqueous medium containing at least one dispersant (also referred to as a detergent). Exemplary grit particles are silicon carbide and diamond. Graves Company of Pompano Beach, Fla. is an example of a commercial supplier of such grit particles. The size of the grit particles may vary. For a 25:1 weight ratio of shearing particles to CNTs—60/90, 120/220, 500/600 silicon carbide grit and 100,000 diamond grit have been practiced. The diameter size of the silicon carbide grit particles are as follows:

Grit Size	Average diameter (microns)
60	254 μm
90	144 μm
120	102 μm
220	63 μm
500	20 μm
600	15 μm
100,000 (diamond)	0.25 μm

(http://stellafane.org/atm/atm_mirror_ref/atm_grit.htm#Grit%20Size%20) and (<http://www.cabbingmachines.com/polishes.shtml>).

[0043] A combination of different size shearing particles may be used, as offered by Graves Company with its PRO-GRIT kit. The grit particles are preferably substantially free-flowing, that is, the particles are not bound to a solid stationary substrate as in the case of sandpaper, so that the particles may flow separately from one another in the tumbler **32** when agitated, e.g., rotated. The grit particles may be spherical or non-spherical, coarse or fine, or grain-like.